Title: The intra- and inter-day reliability of the FitroDyne as a measure of multi-jointed muscle function

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ABSRACT

Background: The FitroDyne has been used to assess muscle function but its reliability has not been determined during traditional multi-jointed resistance exercises. **Objective:** To assess the intra- and inter-day reliability of the FitroDyne during traditional resistance exercises. **Methods:** 14 resistance trained males completed a one repetition maximum (1RM) and three repetitions of bench press, squat and bent-over-row in 10% increments (from 20 to 80%). Replica trials were completed two and 48 hours later. The FitroDyne rotary encoder measured barbell velocity during each repetition from which power output was calculated. **Results:** For all loads and exercises the intra-day typical error (TE) for peak and mean power, and velocity, respectively, during bench press (8.2-53 W and 2.2-6.9 $cm \cdot s^{-1}$), squat (13.3-55.6 W and 2.4-7.4 $cm \cdot s^{-1}$), and bent-over-row (14.5-62.8 W and 4-10.5 $cm \cdot s^{-1}$) identified only moderate changes. Bench press yielded poor intra-day reliability at 80% 1RM only (CV% = 12.2-17.1), whereas squat and bent-over-row across all loads for peak and mean power and velocity displayed better reliability CV% = 2.4-9.0). Inter-day, the TE detected moderate changes for peak and mean power and velocity for all three exercises. Inter-day reliability was comparable to intra-day, though improved for bench press 80%1RM (CV% = 6.1-8.6). **Conclusion:** These data support the use of the FitroDyne at submaximal loads for monitoring moderate changes in muscle function both intra- and inter-day.

KEY WORDS

Power, velocity, reproducibility, bench press, squat, bent-over-row

1. INTRODUCTION

Resistance training is widely used by strength and conditioning practitioners to advance athletic performance. Acute responses to resistance exercise result in impaired muscle function as a consequence of exercise-induced muscle damage [1-6]. Losses in muscle function for up to a week after resistance exercise of ~21% (~60 $N \cdot m^{-1}$) and ~28% (~140 $N \cdot m^{-1}$) have been reported in physically active males for upper[4] and lower body[6], respectively. However, used over a more extended period of time, resistance training programmes provide performance-related benefits, including increased power production[7], muscle strength[8], improved body composition[8], vertical jump height[9] and sprint speed[9]. Resistance training is typically periodised over a period of time by manipulating training volume (repetitions x sets x load) to enhance physiological adaptation[10]. Over 6-12 weeks, such programmes demonstrate improvements of ~11-25% in maximal strength[10] and ~4-29% in muscle power[11-13].

These changes in muscle function are routinely assessed using having the participant perform a maximal voluntary contraction, against a fixed arm (isometric) or an arm moving at a constant angular velocity (isokinetic). Both approaches have been used successfully to quantify the extent of muscle damage and the time course to recovery[1-6,14] and adaptions to training[15]. However, their use often limits the real-world application of such findings as they fail to replicate the multi-jointed and dynamic nature of sporting movements and resistance training[16]. Moreover, the non-involvement of the stretch-shortening cycle[17] and poor to moderate relationship with measures of athletic performance[15, 17] further impacts on the 'real world' validity of isokinetic and isometric muscle tests.

While the use of single-jointed dynamometry might be owing to the absence of more sophisticated measurement tools, the emergence a decade ago of rotary encoders (e.g. FitroDyne) has enhanced the possibilities for assessing muscle function during multi-jointed movements. Rotary encoders are devices that convert the motion into an analogue reading (e.g. power or velocity) via a rotating wheel tether and have been used the assess muscle function[18]. Despite a high level of reliability being reported for this device in quantifying muscle power during single-jointed (bicep curl) or ballistic (squat jump) exercise[19] and bar velocity during bench press[20], no study has determined its reliability during more traditional, multi-jointed resistance exercises that are habitually used in strength and conditioning training. Furthermore, given the need to assess acute alterations in muscle function pre- and immediately postintervention (i.e. intra-day[3]), the authors are unaware of any such study that has established the intra-day reliability of upper body pushing and pulling movements. Whether for athlete support or inclusion in research, the importance of certifying that a measurement tool is reliable is acknowledged[21]. By determining both the intra- and inter-day reliability it can be accepted that an instrument is capable of detecting changes through interventions and not technical error or biological variation. As such, the purpose of this study is to assess the intra- and inter-day reliability of the FitroDyne during bench press, squat and bent-over-row movements as measures of multi-jointed muscle function.

2. METHODS

2.1 Subjects

Fourteen healthy males (see Table 1) were recruited to the study via convenience sampling. All were asymptomatic of illness and injuries, had resistance trained for at least two years and were accustomed to the exercises used. The participants provided written informed consent and the study was granted approval from the Research Ethics Committee of the Faculty of Life Sciences.

[Insert Table 1 about here]

2.2 Design

The study incorporated a repeated measures design and a conceptual replication of Jennings et al.[19]. Participants first attended the laboratory for a familiarisation trial, during which anthropometric measurements (stature, body mass and body composition prediction) were followed by multiple resistance trials at various loads of the selected exercise performed until their power output values plateaued[22]. That is, they were considered to be ‘familiarised’ when they could complete three successive repetitions that yielded power outputs within 10% of each other. The participants returned to the laboratory 48 hours later for trial 1 in which they completed three repetitions of bench press, squat and bent-over-row at various loads. Replica trials - 2 and 3 - were conducted two and 48 hours later, respectively.

2.3 Strength testing

Participants’ maximum strength on the bench press and bent-over-row exercises were assessed by a standardised direct 1RM protocol, as in Stock et al.[20]. One repetition maximum for squat exercise was predicted via a five-repetition maximum (5RM) protocol, for safety reasons, in the manner outlined by Reynolds, Gordon and Robergs[23], and from the equation:

$$1\text{RM (kg)} = 1.0970 \times (5\text{RM weight [kg]}) + 14.2546$$

The above equation was reported to yield accurate 1RM predictions (R^2 = 0.974, SEE = 13.51 kg) by Reynolds et al.[23].

2.4 Assessment of muscle function

During the three repeated trials, peak and mean power and velocity were assessed on the three exercises at loads corresponding to 20, 30, 40, 50, 60, 70 and 80% of the 1RM values in a randomised order via the FitroDyne apparatus (Fitronic, Bratislava, Slovakia) attached directly under a bearing-supported linear raise Smith machine bar (Smith Machine standard, Perform Better, Leicester, UK) by its nylon cable (< 2 N resistance). The FitroDyne measures rate of displacement (at 100 Hz) and thus assumes that the nylon cord is moving in a vertical plane. Any deviation from this plane could increase measurement error. As such the Smith machine, with a 20 kg barbell, was employed as it restricts the movement of the nylon cord to the vertical plane only.

For the bench press exercise, the participant held the bar with a prone grip and lowered it to his chest in a controlled manner, before maximally pushing it until full elbow extension. For the squat exercise, the bar was positioned across the shoulders. Participants descended until their hips were below the knee joint and ascended it as rapidly as possible until their knees were at full extension. A bench was employed to ensure that they attained the same depth and range of motion on each repetition. Muscle function for the bent-over-row exercise was determined with the participant commencing in a bent-over position, before pulling the bar maximally until the elbows reached full flexion. Three repetitions of each exercise were performed at each load with self-selected rest intervals that were capped at 90 s, but ranged from 30-90 s[19]. Rest times were self-selected, as lighter loads did not require the same recovery time. Peak and mean velocity values recorded from these trials were used in the data analysis. The exercise and load sequence was randomised for each participant to negate possible order effects.

2.5 Statistical Analysis

All data collected were analysed using SPSS (version 21, IBM SPSS Inc, Chicago, IL). Peak and mean values for power and velocity for the three repetitions at each load were used in the assessment of the intra- (trial 1 versus trial 2) and inter-day (trial 1 versus trial 3) reliability of the FitroDyne. The assumption of normality of the distributions of the dependent variables was checked via the Shapiro-Wilk statistic and found to be satisfied ($P > 0.05$). Accordingly, a one-way repeated measures analysis of variance (ANOVA) was conducted to test for systematic error between the trials. Alpha was set at 0.05.

Having established that the differences (errors) were found to be homoscedastic, the trial-to-trial reliability of the FitroDyne data was quantified via the typical error (TE; standard deviation of the differences divided by √2), coefficient of variation (CV; TE divided by the grand mean test-retest score, multiplied by 100) statistics, as described by Hopkins[24]. It has been argued that TE is preferable to 95% limits of agreement (95% LoA) technique as the latter is too stringent to detect meaningful changes in sports/exercise performance[24]. Moreover, the smallest worthwhile change (SWC; 0.2 multiplied by the shared standard deviation) and moderate change (MC; SWC multiplied by 3) were calculated to provide a 'real world' application of the findings. To detect genuine training-related reductions in muscle function via multi-jointed measures, the dependent variables were considered capable of detecting small or moderate changes if the TE was smaller than the SWC or MC, respectively[25].

3. RESULTS

The descriptive statistics for the muscle function variables of each exercise across the three trials (at each load) are presented in Figures 1-3. ANOVA revealed no significant ($P > 0.05$) bias in each variable between trials 1 and 2 at any load. For all the dependent variables and exercises the TE was greater than the SWC, but smaller than the MC intra-day across all loads (Tables 2-4). The best intra-day reliability for bench press was noted for peak power at 40% 1RM (TE and CV = 10.1 W and 1.6 %, respectively). The lowest levels of reliability were displayed for the intra-day bench press at the 80% intensity for peak and mean power and mean velocity, with TEs of 53 (CV = 12.2%) and 44.2 W (CV = 17.1%) and 4.3 (CV = 13.4%) $cm \cdot s^{-1}$, respectively. Squat across all loads for peak power, mean power, peak velocity and mean velocity displayed TEs of 21.8-73.3 W (CV = 2.4-6.1%), 8.7-29.6 W (CV = 2.4-6.4 %), 3.9-8.1 $cm \cdot s^{-1}$ (CV = 2.7-5.8%) and 2-4.2 $cm \cdot s^{-1}$ (CV = 2.2-6.4%), respectively. For bent-over-row, the intra-day reliability was generally better, with the poorest levels of agreement observed for mean velocity at 70%1RM (TE and CV = 6.7 $cm \cdot s^{-1}$ and 9%, respectively).

[Figures 1, 2 and 3 about here]

Similarly, ANOVA revealed no significant bias ($P > 0.05$) for any exercise, load or variable between trials 1 and 3. For the inter-day reliability, the TE for peak power, mean power, peak velocity or mean velocity, was unable to detect the small (i.e. SWC), across any exercise or load, but was able to identify the MC (Tables 2-4). Bench press demonstrated similar inter-day reliability to intra-day reliability at loads of 20-70%1RM. Interestingly, inter-day reliability for peak and mean power and mean velocity at 80% was better, with TEs of 32.1 (CV = 7.1%) and 22.5 W (CV = 8.6%) and 2.6 (CV = 8.2%) $cm \cdot s^{-1}$, respectively. Inter-day reliability for squat was similar to the intra-day results for all dependent variables across all loads, while for bent-over-row it was comparable to the intra-day reliability across all loads for peak power, mean power, peak velocity and mean velocity.

[Insert Table 2-4 about here]

4. Discussion

This study has observed that measures of muscle function assessed via the FitroDyne can be reproduced within acceptable limits both intra- and inter-day. Importantly, they suggest that the FitroDyne can be used with confidence to monitor moderate changes among athletes during multi-jointed exercise, either in detecting fatigue, muscle damage or as a result of training adaptation, independently of an athlete's power.

The threshold of reliability of a measurement tool is dependent on the setting it is applied in[21]. After muscle-damaging exercise acute decrements in muscle function ranging from 14.5-28.2% are typically observed[1, 2, 3-5], while increases in muscle strength and muscle power are 11-25 and ~4-29%, respectively[10-13].

Accordingly, a variation of up to 10% would allow for suitable detection of changes in muscle function in these settings. Though, this emphasises the CV%, the TE, SWC and MC should be incorporated to support the interpretation of the reliability data. Few studies adopt ‘analytical goals’, but their consideration adds value to the analysis of the findings[26].

These data have demonstrated that intra-day the FitroDyne can detect moderate, but not small, changes in power and velocity for bench press. Comstock and colleagues[27] noted an intra-class correlation coefficient (ICC) of ≥ 0.96 for bench throw at 30% 1RM. For comparative purposes, the bench press intra-day ICC in this study was 0.98. Moreover, peak and mean power and velocity were deemed reliable at loads up to 70% 1RM. At 80% 1RM, however, peak and mean power and mean velocity displayed unacceptable intra-day reliability (TEs of 53 and 44.2 W and 4.3 $cm \cdot s^{-1}$, respectively) as all CV% were greater than the analytical goal. Bench press peak velocity intra-day reliability was better, at 9.7 CV%, but close to the threshold.

Such low intra-day reliability for bench press at 80% 1RM might reflect the presence of fatigue from trial 1. That is to say, the recovery from trials 1 to 2 was insufficient to enable the restoration of muscle function, particularly for low velocity, high force movements. That we observed larger, albeit not significant decrements in velocity and power at 80% 1RM from trials 1 to 2 compared to 1 to 3, supports this notion. Slower movement velocities (80 and 90% 1RM) have also been reported to possess the poorest reproducibility[20]. While the reasons are not entirely clear, Stock et al.[20] speculated that the FitroDyne device might not be able to detect small differences in slow movement velocities. The applied practitioner should be confident in identifying moderate changes in upper pushing power and velocity at 20-70% 1RM, but not at 80% 1RM.

Small intra-day TE and CV% for squat exercise velocity (2-8.1 $cm \cdot s^{-1}$ and 2.2-6.4%, respectively) and power (8.7-73.3 W and 2.4-6.4%, respectively) suggested that the movement was repeatable. These findings are consistent with Cormack et al.[29] who, like this study, noted that intra-day TE was not able to detect the SWC and produced CVs of 3.5 and 6.9% for peak and mean power, respectively. During squat jump exercise at 30% 1RM Comstock et al.[27] observed an intra-day ICC of $\geq$ 0.96, similar to the current study's ICC of 0.95 at 30% 1RM. Regarding the application of these findings, Byrne and colleagues[3] quantified decrements of 23.2 and 29.7% in isokinetic torque at slow (0.52 $rad \cdot s^{-1}$) and fast (3.14 $rad \cdot s^{-1}$) angular velocities, respectively. At all exercise loads, the CV%s for power and velocity reflect that the FitroDyne would be able to detect these changes observed by Byrne et al.[3].

Until now no study has assessed the intra-day reliability of upper body pulling power or velocity. This study reports a high degree of reliability for the assessment of power and velocity during bent-over-row exercise across a range of loads. These findings suggest that bent-over-row can be used with confidence to assess moderate intra-day changes in an applied setting. Similar to bench press and squat, we recommend the use of the FitroDyne to quantify moderate changes in pulling exercise after muscle-damaging exercise. However, the paucity of research on pulling exercises means it is difficult to relate such reliability to known power or velocity changes after resistance training.

The *inter*-day reliability for bench press peak and mean power and velocity was generally similar to the intra-day reliability at loads of 20-70% 1RM, but superior at 80% 1RM (TE of 32.1 and 22.5 W and 2.6 $cm \cdot s^{-1}$ and CVs of 7.1, 8.6 and 8.2% for peak and mean power and mean velocity, respectively), though in all cases the TE was only able to detect the MC. This enhanced reliability might be due to sufficient time to off-set fatigue, illustrated in the restoration of velocity at this load. During bench press Stock et al.[20] observed CVs of 3.1 and 12.6% for inter-day peak velocity at 10-90% 1RM, Drinkwater et al.[28] found that a TE of 14 W, at 40 kg (no relative load noted), was not able to detect the SWC. After eight weeks of strength training Turbanski and Schmidtbleicher[13] noted a 10 $cm \cdot s^{-1}$ (4.2%) improvement in maximum velocity during bench press exercise. This change might be detectable using the FitroDyne as the TE calculated in this study was 6.7 $cm \cdot s^{-1}$ (CV

= 3.2%) at 20% 1RM, which produced the fastest velocity. Furthermore, a 37.3 W (15.5%) improvement in bench press power during a progressive resistance test has been noted following higher volume resistance training. While there are no direct load comparisons, the worst TE and CV (34.2 W and 7.1%) are low enough to detect the aforementioned improvements. Additionally, acute decrements of 28.2 and 21.9% (140.4 and 108.9 $N \cdot m^{-1}$;[6]) in pushing force 24 and 48 hours post muscle-damaging exercise are within the threshold of the FitroDyne's measurement error.

Inter-day reliability for squat exercise was, as for bench press, similar to intra-day. The TEs for power and velocity of 8.7-73.3 W (CV = 2.4-6.1%) and 2.0-8.1 $cm \cdot s^{-1}$ (CV = 2.2-5.8%) respectively, reinforced the FitroDyne's ability to detect moderate changes. Such interpretations, of 'good reliability' agree with previous reports, albeit the statistics are not directly comparable[19, 27, 29]. For example, Jennings et al.[19] reported an ICC of 0.97 and 95% LoA of -17 ± 96 W for squat jump peak power, whilst we noted an ICC of 0.91 and 95% LoA of 11.1 ± 271 W (not included in results) for peak power. As decrements in lower limb muscle function are large (14.5-20.9%[1, 2, 4, 5]), our findings indicate the FitroDyne in capable of detecting such changes across a range of exercise loads. However, the typically small (5.6%) improvements in muscle power during squat following 6 weeks resistance training are lower than the

TE and CV% and therefore challenges the FitroDyne's sensitivity to detect this.

With respect to bent-over-row exercise, our findings reflect levels of reliability – TE and CVs for power (10.3-68.8 W and 2.6-8.5%) and velocity (3.7-9.5 $cm \cdot s^{-1}$ and 2.3-8.8%) – that were mostly low and sufficient to detect moderate changes in muscle function. Though there are no reports of acute muscle functional changes for this exercise after resistance training, the study by Naclerio et al.[11] involving six week of resistance training yielded a 37.3 W (13.5%) improvement in upright row pulling power during a progressive resistance test. Despite mechanical differences of upright rows when compared to bent-over-row, the TEs in our study are too high to detect such adaptations. As with bench press and squat, it is recommended that the FitroDyne be used to assess muscle-damaging exercise provided the expected changes are not less than moderate.

Applied practitioners should be mindful that these findings were observed on a fixed vertical plane of motion during Smith machine exercise. The Smith machine was employed in order to avoid any deviation from a vertical plane as this could increase measurement error. Consequently, the reliability noted might not always be representative of free weight barbell movements. Future research might seek to determine if measurement error differs between resistance exercises performed on a Smith machine compared to free weight barbell appartus.

5. Conclusions

This is the first study, to our knowledge, to provide a comprehensive appraisal of the reliability of muscle function measures during traditional multi-joint resistance exercises using a commercially available rotary encoder. The device's intra-day reliability indicated it could detect moderate, but not small, changes for all exercises and loads for peak and mean power and velocity. For bench press, intra-day reliability for loads up to 70% 1RM was good, but less so at 80% 1RM, possibly owing to the associated low velocity, or acute fatigue from the previous testing protocol. Squat and bent-over-row intra-day reliability was good throughout. These data support the use of the FitroDyne to quantify acute intra-day changes in muscle function. Inter-day reliability was similar to intra-day for all exercises, and better at the highest tested intensity (80% 1RM) for bench press. Overall, our findings suggest that the FitroDyne can be used with confidence to assess muscle function during traditional resistance training exercise and to measure acute changes in muscle function across a range of submaximal loads. The applied practitioner should, however, be cautious when assessing muscle-function intra-day at 80%

1RM during bench press exercise. In addition, the FitroDyne provides an alternative to the use of single-jointed isometric and isokinetic dynamometry in the assessment of muscle function.

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Table 1: Participant characteristics.

Characteristic	Mean ± SD
Age (y)	22.6 ± 4.9
Mass (kg)	83.2 ± 8.1
Stature (m)	1.80 ± 0.10
Fat mass (kg)	10.0 ± 4.3
Fat free mass (kg)	73.2 ± 7.4
Bench press 1RM (kg)	102.5 ± 19.0
Squat 1RM (kg)	132.2 ± 26.2

Bent-over-row 1RM (kg)	94.8 ± 14.5

Table 2. Reliability statistics for peak and mean power and velocity during bench press exercise.

		Peak Power				Mean Power				Peak Velocity				Mean Velocity			
Load (%1RM)	**Trial**	**TE (W)**	**SWC (W)**	**MC (W)**	**CV (%)**	**TE (W)**	**SWC (W)**	**MC (W)**	**CV (%)**	**TE (cm·s^{-1})**	**SWC (cm·s-1)**	**MC (cm·s-1)**	**CV (%)**	**TE (cm·s-1)**	**SWC (cm·s-1)**	**MC (cm·s-1)**	**CV (%)**
20	*1 v 2*	18.3	7.7	23.2	4.3	8.2	3.5	10.5	3.4	6.9	2.9	8.8	3.3	3.4	1.5	4.4	2.9
	1 v 3	17.0	7.2	21.7	4.0	13.8	5.9	17.6	5.7	6.7	2.8	8.5	3.2	5.1	2.2	6.5	4.3
30	*1 v 2*	11.3	4.8	14.3	2.1	8.4	3.6	10.7	2.6	3.1	1.3	3.9	1.7	2.9	1.2	3.7	2.7
	1 v 3	14.1	6.0	17.9	2.6	13.1	5.6	16.7	4.1	4.1	1.7	5.2	2.2	3.7	1.6	4.7	3.5
40	*1 v 2*	10.1	4.3	12.8	1.6	11.0	4.7	14.0	2.9	2.8	1.2	3.6	1.8	2.9	1.2	3.7	3.1
	1 v 3	13.4	5.7	17.1	2.2	11.5	4.9	14.6	3.1	3.3	1.4	4.1	2.1	2.8	1.2	3.6	3.0
50	*1 v 2*	16.9	7.2	21.5	2.6	10.7	4.5	13.6	2.7	3.6	1.5	4.5	2.8	2.2	1.0	2.9	2.8
	1 v 3	28.0	11.9	35.7	4.4	18.6	7.9	23.6	4.7	5.8	2.5	7.4	4.6	4.0	1.7	5.1	5.1
60	*1 v 2*	23.8	10.1	30.3	4.0	17.7	7.5	22.5	4.6	3.8	1.6	4.9	3.9	2.8	1.2	3.5	4.4
	1 v 3	27.8	11.8	35.4	4.6	16.2	6.9	20.7	4.2	4.3	1.8	5.5	4.3	2.4	1.0	3.1	3.8
70	*1 v 2*	18.6	7.9	23.6	3.4	16.4	7.0	20.9	4.8	2.6	1.1	3.2	3.3	2.2	0.9	2.8	4.5
	1 v 3	34.2	14.5	43.5	6.4	21.6	9.2	27.5	6.4	4.5	1.9	5.7	5.9	3.0	1.3	3.8	6.2
80	*1 v 2*	53.0	22.5	67.5	12.2	44.2	18.7	56.2	17.1	5.3	2.3	6.8	9.7	4.3	1.8	5.4	13.4
	1 v 3	32.1	13.6	40.8	7.1	22.5	9.6	28.7	8.6	3.4	1.5	4.4	6.1	2.6	1.1	3.3	8.2

Table 3. Reliability statistics for peak and mean power and velocity during squat exercise.

		Peak Power				Mean Power				Peak Velocity				Mean Velocity			
Load (%1RM)	**Trial**	**TE (W)**	**SWC (W)**	**MC (W)**	**CV (%)**	**TE (W)**	**SWC (W)**	**MC (W)**	**CV (%)**	**TE ($cm \cdot s^{-1}$)**	**SWC (cm·s-1)**	**MC (cm·s-1)**	**CV (%)**	**TE (cm·s-1)**	**SWC (cm·s-1)**	**MC (cm·s-1)**	**CV (%)**
20	*1 v 2*	21.8	9.2	27.7	4.9	13.3	5.6	16.9	5.3	7.0	3.0	9.0	4.1	3.9	1.6	4.9	4.0
	1 v 3	22.5	9.6	28.7	4.9	11.5	4.9	14.7	4.5	6.5	2.8	8.3	3.7	3.9	1.7	5.0	4.0
30	*1 v 2*	34.6	14.7	44.1	5.4	19.9	8.4	25.3	5.6	7.4	3.1	9.4	4.5	4.2	1.8	5.4	4.6
	1 v 3	27.6	11.7	35.2	4.3	8.7	3.7	11.1	2.4	5.9	2.5	7.6	3.6	2.0	0.9	2.6	2.2
40	*1 v 2*	35.2	14.9	44.8	4.3	28.2	12.0	35.9	6.4	6.1	2.6	7.8	4.0	4.8	2.0	6.1	5.7
	1 v 3	35.5	15.0	45.1	4.4	16.5	7.0	21.0	3.8	6.2	2.6	7.9	4.0	3.3	1.4	4.3	4.0
50	*1 v 2*	22.8	9.7	29.0	2.4	14.2	6.0	18.1	2.9	3.9	1.7	5.0	2.7	2.4	1.0	3.1	3.2
	1 v 3	54.3	23.0	69.0	5.8	24.3	10.3	31.0	4.9	8.1	3.4	10.3	5.7	4.2	1.8	5.3	5.5
60	*1 v 2*	36.7	15.6	46.7	3.5	22.3	9.4	28.3	4.1	4.5	1.9	5.7	3.3	3.0	1.3	3.8	4.3
	1 v 3	54.9	23.3	69.9	5.3	22.4	9.5	28.6	4.2	7.0	3.0	8.9	5.3	3.1	1.3	3.9	4.5
70	*1 v 2*	55.6	23.6	70.8	4.9	29.6	12.6	37.7	5.4	6.4	2.7	8.2	5.2	3.8	1.6	4.8	6.3
	1 v 3	64.6	27.4	82.2	5.7	21.9	9.3	27.9	4.0	6.9	2.9	8.8	5.6	2.5	1.1	3.2	4.2
80	*1 v 2*	46.7	19.8	59.5	3.9	28.4	12.1	36.2	5.5	5.1	2.2	6.5	4.4	3.1	1.3	4.0	6.4
	1 v 3	73.3	31.1	93.3	6.1	23.4	9.9	29.7	4.4	6.8	2.9	8.6	5.8	2.6	1.1	3.3	5.2

Table 4. Reliability statistics for peak and mean power and velocity during bent-over-row exercise.

		Peak Power				**Mean Power**				**Peak Velocity**				**Mean Velocity**			
Load (%1RM)	**Trial**	**TE (W)**	**SWC (W)**	**MC (W)**	**CV (%)**	**TE (W)**	**SWC (W)**	**MC (W)**	**CV (%)**	**TE (cm·s^{-1})**	**SWC (cm·s-1)**	**MC (cm·s-1)**	**CV (%)**	**TE (cm·s-1)**	**SWC (cm·s-1)**	**MC (cm·s-1)**	**CV (%)**
20	*1 v 2*	18.9	8.0	24.0	5.1	14.5	6.2	18.5	6.6	8.8	3.7	11.2	4.4	6.6	2.8	8.5	5.6
	1 v 3	15.2	6.4	19.3	4.0	10.3	4.4	13.1	4.6	7.6	3.2	9.6	3.7	5.4	2.3	6.8	4.5
30	*1 v 2*	20.0	8.5	25.5	3.8	23.0	9.7	29.2	7.4	7.1	3.0	9.0	3.8	8.7	3.7	11.1	7.9
	1 v 3	15.1	6.4	19.2	2.9	17.2	7.3	21.9	5.5	5.9	2.5	7.5	3.2	7.0	3.0	8.9	6.3
40	*1 v 2*	21.6	9.2	27.5	3.5	16.3	6.9	20.7	4.3	6.1	2.6	7.7	3.7	4.8	2.0	6.1	4.7
	1 v 3	24.1	10.2	30.7	3.9	20.4	8.6	25.9	5.4	4.9	2.1	6.3	2.9	4.7	2.0	6.0	4.7
50	*1 v 2*	20.8	8.8	26.5	2.9	26.7	11.3	33.9	6.1	4.0	1.7	5.1	2.6	6.0	2.6	7.7	6.4
	1 v 3	18.6	7.9	23.7	2.6	25.8	11.0	32.9	5.9	3.7	1.6	4.7	2.3	5.8	2.5	7.4	6.2
60	*1 v 2*	33.0	14.0	42.1	4.1	33.0	14.0	42.0	6.9	5.7	2.4	7.2	4.0	6.4	2.7	8.1	7.5
	1 v 3	41.0	17.4	52.2	5.2	34.9	14.8	44.4	7.3	5.9	2.5	7.5	4.1	6.3	2.7	8.0	7.4
70	*1 v 2*	62.8	26.7	80.0	7.8	40.0	17.0	50.9	8.2	10.5	4.4	13.3	8.5	6.7	2.8	8.5	9.0
	1 v 3	53.3	22.6	67.8	6.6	33.0	14.0	42.0	6.8	8.0	3.4	10.1	6.4	4.8	2.1	6.2	6.6
80	*1 v 2*	61.1	25.9	77.8	7.7	37.3	15.8	47.4	7.8	8.8	3.7	11.2	8.3	5.4	2.3	6.9	8.5
	1 v 3	68.8	29.2	87.5	8.5	28.8	12.2	36.6	6.0	9.5	4.0	12.0	8.8	3.7	1.6	4.7	5.9

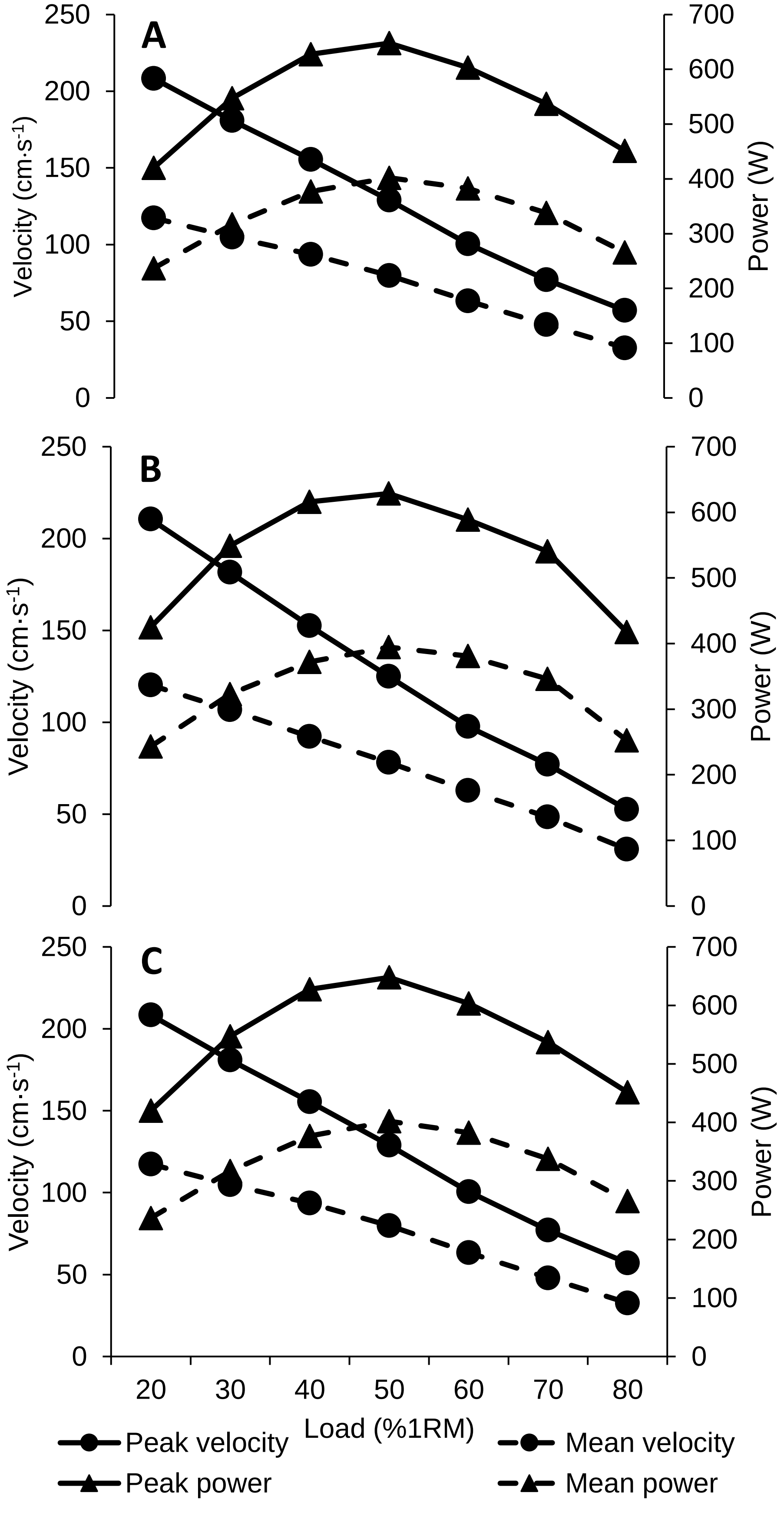

Figure 1. Sample mean values for peak power, mean power, peak velocity and mean velocity for bench press during trials 1 (A), 2 (B) and 3 (C).

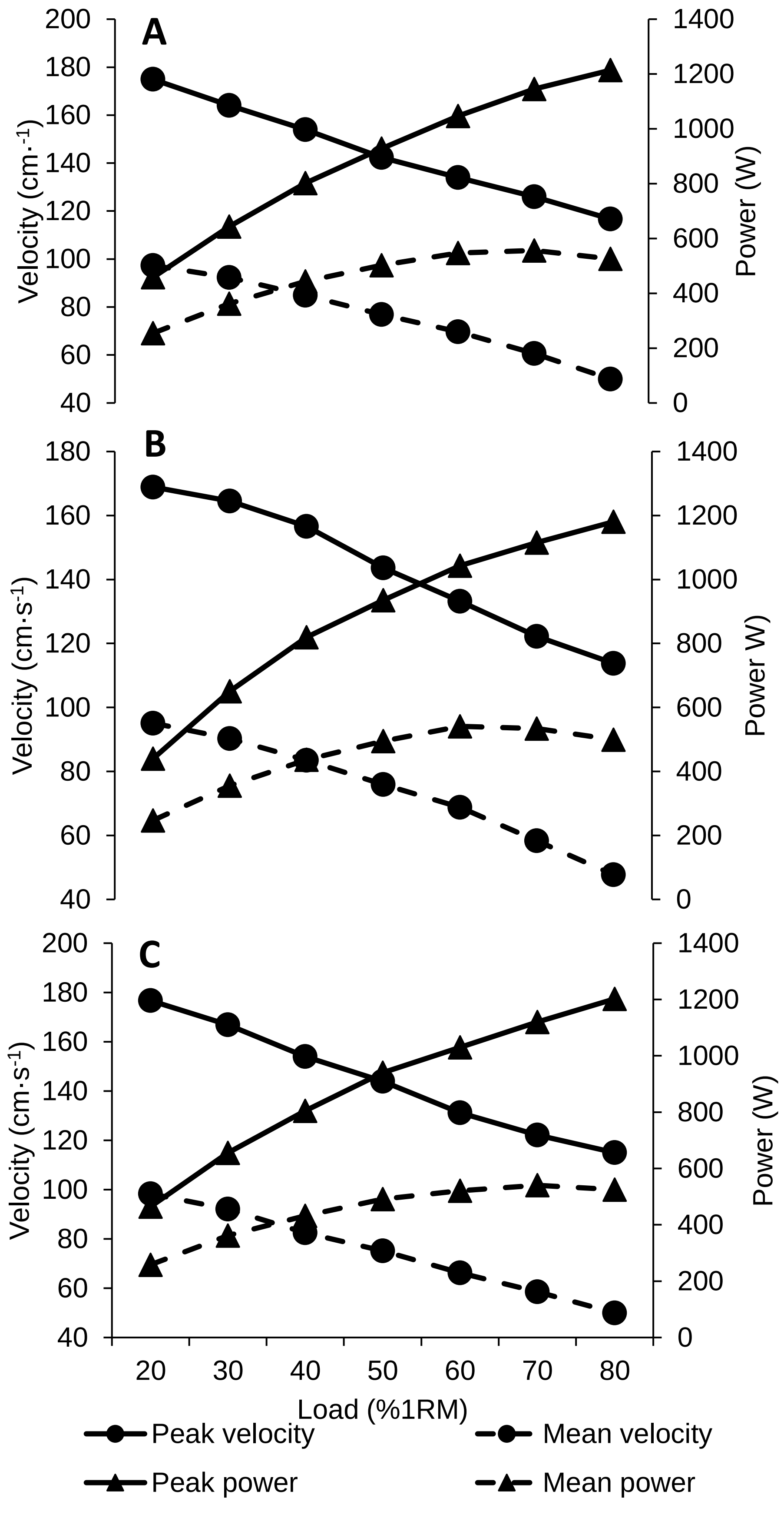

Figure 2. Sample mean values for peak power, mean power, peak velocity and mean velocity for squat during trials 1 (A), 2 (B) and 3 (C).

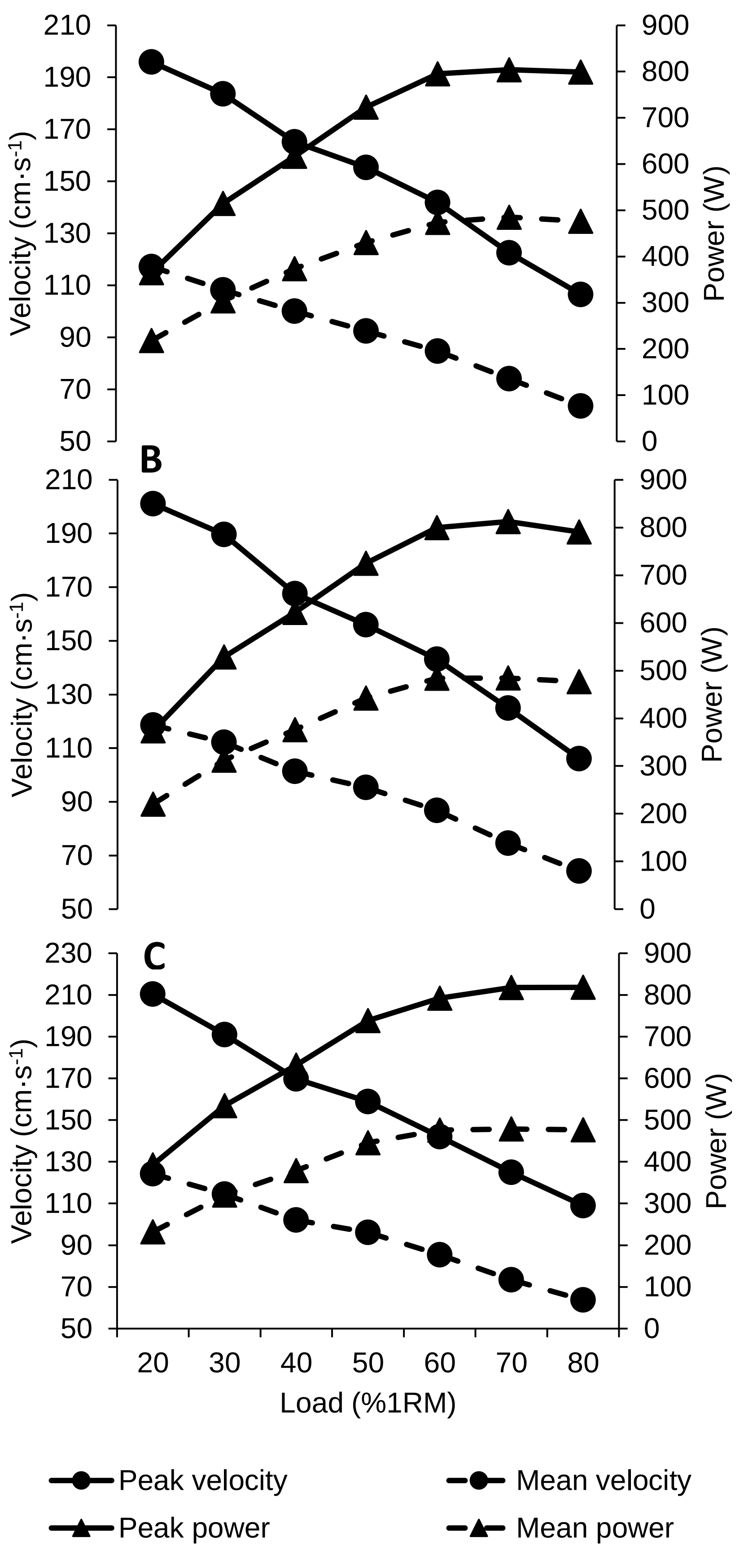

Figure 3. Sample mean values for peak power, mean power, peak velocity and mean velocity for bent-over-row during trials 1 (A), 2 (B) and 3 (C).